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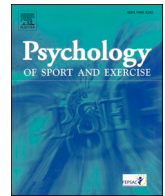
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When in doubt, it's not out: Match format is associated with differences in elite-level cricket umpires' leg-before-wicket decisions[☆]

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ABSTRACT

Objectives: Contextual factors can influence the way sports officials apply unambiguous rules. The aim of this study was to better understand the leg-before-wicket (LBW) decision-making behaviour of elite cricket umpires and determine whether their behaviour changes according to the format of the game in which they are adjudicating.

Methods: LBW decisions ($n = 5578$) from actual elite level cricket matches in Australia between 2009 and 2016 were analysed using a signal detection paradigm. Umpire sensitivity (A) and response bias (B) were compared to chance performance in three formats of the game: Four-day, One-day, and T20. Mixed effects models assessed sensitivity and response bias differences between match types.

Results: Umpires were able to differentiate between “out” and “not out” appeals to a high standard but were conservative and had a bias to respond “not out” in all formats of the game. Umpires were less accurate in the shorter formats of the game, particularly T20 cricket and were also significantly more conservative in T20 compared to Four-day Matches.

Conclusions: Cricket umpires are conservative and are highly accurate LBW decision makers. However, differences in their judgments were associated with different match formats. The unique task goals and contextual pressures afforded by the shorter formats of the game, particularly T20, may account for the observed performance differences we see here.

Experts can make decisions under pressure with remarkable speed and precision. Fingerprint examiners can rapidly and accurately match prints (Thompson & Tangen, 2014), medical doctors can differentiate abnormal from normal tumours in low resolution scans (Evans, Georgian-Smith, Tambouret, Birdwell, & Wolfe, 2013), and chess masters identify strategy on a chess board in a fraction of a second (Chase & Simon, 1973). In professional sport, players and spectators expect similar feats of human judgement from referees and umpires when making judgements based on the unambiguous rules of their chosen sport. These judgements however can be shaped by contextual factors, such as foul judgements being influenced by previous decisions (Plessner & Betsch, 2001), home advantage (Courneya & Carron, 1992), crowd noise (Nevill, Balmer, & Williams, 2002; Unkelbach & Memmert,

2010), and even jersey colour (Frank & Gilovich, 1988; Greenlees, Eynon, & Thelwell, 2013; Hagemann, Strauss, & Leijning, 2008). For instance, borderline pitch calls in baseball are influenced by pitch/ball counts such that a borderline pitch is more likely to be judged a ball if strikes have been called previously or as a strike if balls have been called (MacMahon & Starkes, 2008). In essence, these contextual factors often lead to errors in decision-making. And given that incorrect decisions can change the outcome of a match, the future career prospects of participants (officials, players and coaches), and have financial repercussions for all, it is vital to know of and eliminate these errors in sports officiating wherever possible (Mascarenhas, Collins, Mortimer, & Morris, 2005).

Leg-before-wicket (LBW) decisions may be the hardest decisions

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umpires are required to make in the sport of cricket. The LBW law requires umpires to adjudicate whether the ball – after hitting the batter – would have gone on to hit the stumps. If so, then the batter can be adjudicated as ‘out’. In LBW judgements, not only do umpires make reactive spatial judgements based on visual information (e.g., where did the ball bounce and hit the batsman, and did it hit their bat before hitting them?), but the judgements are also unique in that the umpire is required to make a *predictive judgement* as to where the ball would have travelled had it not hit the batter. Prior to this, the umpire must judge whether the ball is ‘legal’ by determining whether the bowler’s front foot landed behind a line at the point of delivery. Previous work by Southgate, Barras, and Kummer (2008) has shown that by attending to the front foot, it is more difficult for umpires to accurately judge where the ball lands.

Only one study to date has explored expert-novice differences in umpire LBW decision-making. Using a temporal occlusion paradigm, where ball flight was stopped either at bounce or two frames post-bounce, Chalkley, MacMahon, and Ball (2013) showed that club-expert, and intermediate-level cricket umpires were able to more accurately predict the flight path of a cricket ball than a novice control group. Given though that expert umpires did not perform better than intermediate umpires, it is possible that the nature of the task failed to sample the true nature of the expertise of those umpires due to a lack of representativeness. More specifically, the isolated video clips used in this study removed almost all contextual information that may differentiate expert and intermediate umpires’ decisions in the real world. This task was, therefore, relatively simple as it provided the participants with only one cue (ball trajectory) to focus upon and so the expertise of the higher-level umpires may not have been revealed due to the issues with (insufficient) representative design (Pinder, Davids, Renshaw, & Araújo, 2011). Further, as umpires did not have to attend to the bowler’s front foot, the task may have been significantly easier (Southgate et al., 2008).

In this study, we aim to gain a better understanding of LBW decision-making in real matches. To do so, we used historical elite-level match data kindly provided by Cricket Australia. We classified umpires as ‘elite’ based on the recommendations of Kittel, Larkin, Elsworth, and Spittle (2019), due to the umpires officiating at the national level in a large sporting nation. In Australia, umpiring performance is assessed using a ‘percentage correct’ metric based on accuracy ratings made after the match by a match referee who reviews video footage after the match and determines whether the on-field umpire made the correct decision. Using this metric of umpire performance may have a number of limitations. Anecdotally, players will appeal to the umpire (request a decision) even when they know this action is unlikely to be given out. This means that umpires are presented with a number of decisions that are clearly not out, which may boost the percentage of decisions that are rated as correct. With this in mind, we assess umpire performance using a signal detection paradigm (Green & Swets, 1966) to take into account the multiple ways to be right (hits and correct rejections) and wrong (misses and false alarms). In this approach, we conceptualise officials’ decisions as categorisation judgements, similar to football referees categorising an event as a foul or not (Plessner, Schweizer, Brand, & O’Hare, 2009). That is, this approach allows us to not only assess umpire decision accuracy, but also determine whether umpires are liberally (tend to give the batter out) or conservatively (tend to give the batter not out) biased. Although there is no specific rule in the laws of cricket, convention dictates that umpires are expected to give the benefit of the doubt to the batsman, due to the fact that batters are only given one chance to contribute to an innings, with a maximum of two innings in test cricket. As such, we predict that umpires will be conservative. That is, they will show a conservative response bias and so tend to respond “not out” in leg-before-wicket decisions. This is in line with recent work by Russell, Renshaw, and Davids (2019), which proposed that officials’ decision are not only shaped by traditional notions of accuracy, but also stakeholder expectations of how the game should be played.

Elite cricket umpires officiate in three distinct game formats: Four/Five-day, One-day, and T20 cricket. The traditional format of the game is played over 4 days at the national level, and 5 days at the international level known as *Test cricket*. Test cricket is considered by many cricketers and fans to be the pinnacle of the sport. One-day cricket is played over 8 hours and encourages a faster pace of play, while T20 represents the fastest format of the game, played over 3 hours, often at night under lights. T20 has been termed the fast-food version of cricket with its inception designed to attract new audiences to the other forms of cricket. The game was designed to be shorter, based on entertainment to appeal to a new, younger audience (Ramsey, 2014). As a result, this format of the game attracts significantly larger crowds than Four-day and One-day matches.

The unique context afforded by the playing conditions of each format shape how players approach the game. For example, batsmen in test cricket take a conservative approach in an attempt to bat for as long as possible, while batsmen in T20 cricket typically opt for a more explosive approach and try to score runs as quickly as possible. However, the LBW law remains identical across all three forms of the game. Given that the context (e.g. laws, player strategies, and crowd sizes) differs greatly across the three forms of the game, we were interested whether umpires LBW decisions were also different across the three formats. For example, differences in crowd sizes between formats may afford different levels of social pressure on umpires, which may influence their decision-making (Di Corrado, Pellarin, & Agostini, 2011). This study therefore aims to determine whether cricket umpire LBW decision sensitivity and response bias differs between match types. These analyses were exploratory, and as such no predictions were made.

1. Method

Historical LBW decision-making data from first class cricket matches across four-day, one-day, and T20 matches was obtained from Cricket Australia for the purpose of this study. The data included the decision made by the umpire (“out” or “not out”), and a rating of the decision from a match referee (“correct”, “incorrect”, or “inconclusive”) for all games between 2009 and 2016. The match referee is the official in charge of both player conduct, and umpire assessment in each match. The match referees’ ratings were subjective and were based on television video footage in all formats. Match referees also have access to ball-tracking software in T20 matches. Decisions were rated as inconclusive if the match referee deemed that there was insufficient evidence to assess the decision accurately. Inconclusive decisions were removed from the dataset ($n = 79$). Correct and incorrect decisions were coded as hits (correct “out” call), misses (incorrect “not out” call), false alarms (incorrect “out” call), and correct rejections (correct “not out”). A total of 5578 observations (18.75% rated as out) from four-day ($n = 4278$, $M = 237.67$, $SD = 162.57$), one-day ($n = 961$, $M = 56.53$, $SD = 33.33$), and T20 matches ($n = 339$, $M = 28.25$, $SD = 12.34$) were included. “M” refers to the average number of decisions made by an umpire in a given format. Umpires were included in the analyses if they had made a minimum of 10 decisions in a match type, resulting in a total of 18 umpires (12 umpires in all three match types, 5 umpires in both four and one-day matches, and 1 umpire in only four-day matches). This meant there were 18 umpires in the Four-day condition, 17 umpires in the One-day condition, and 12 umpires in the T20 condition.

First, we report descriptive performance statistics in the form of hit and false alarm rates. These rates then underwent a log-linear correction to account for extreme values (Hautus, 1995) and were used to calculate umpire sensitivity (A) and response bias (B) to compare umpire performance (see Zhang and Mueller (2005) for the correct calculation of A rather than A’). Sensitivity scores range from 0 to 1, with 0.5 meaning chance discrimination between outs and not outs, and 1 meaning umpires can perfectly discriminate outs from not outs. Response bias scores <1 indicate a liberal response bias (that is, a tendency to respond “out” regardless of whether the player is actually out or not) and scores >1

indicate conservative response bias (that is, a tendency to respond “not out” regardless of whether the player is actually out or not).

First, Wilcoxon Signed Rank Tests were performed in IBM SPSS Statistics 25 to compare sensitivity scores to chance ($A = 0.5$), and response bias scores to that where there is no bias ($B = 1$). Next, linear mixed effects models with match type as a fixed effect, and umpires as a random effect were performed to account for missing data within umpires, followed by Sidak post-hoc pairwise comparisons.

2. Results

Overall, umpires’ decisions were rated as correct 98.08% of the time. In Four-Day matches, umpires had a Hit rate of 96.20% ($SD = 4.23$) and a False Alarm rate of 0.87% ($SD = 0.99$). In One-Day matches, umpires had a Hit rate of 96.29% ($SD = 5.43$) and a False Alarm rate of 2.16% ($SD = 2.48$). In T20 matches, umpires had a Hit rate of 86.15% ($SD = 14.77$) and a False Alarm rate of 2.04% ($SD = 2.71$). The individual Hit and False Alarm rates of umpires in Four-day, One-day, and T20 matches is illustrated in Fig. 1. The hit rate (left) represents each umpire’s performance when the batter should have been given out and indicates how often umpires do give them out (hit) versus give them not out (miss). The false alarm rate (right) represents how often umpires erroneously give a batter out (false alarm) when they should have been given not out (correct rejection). These hit and false alarm rates were log-linear corrected and then combined to form measures of sensitivity (A) and response bias (B).

2.1. Sensitivity

Three one-sample Wilcoxon Signed Rank Tests showed that umpires were able to discriminate between outs and not outs significantly better than chance in Four-Day ($Z = 3.72$, $p < .001$, $r = 0.88$), One-day ($Z = 3.62$, $p < .001$, $r = 0.88$), and T20 matches ($Z = 3.06$, $p = .002$, $r = 0.88$). A Mixed Effects model with Match Type as a fixed effect, and umpire as a random effect revealed a significant main effect of match type on umpire sensitivity with a large effect size ($F(2, 14.56) = 21.15$, $p < .001$, $\eta_p^2 = 0.74$). Umpires were significantly more sensitive in Four-Day matches compared to both One-Day with a small effect size ($p = .006$, Cohen’s d [95% CI] = 0.17 [-0.49, 0.83]), and T20 Matches with a small effect size ($p < .001$, Cohen’s d [95% CI] = 0.39 [-0.35, 1.13]). There was also a significant difference between One-Day and T20 matches with a small effect size ($p = .026$, Cohen’s d [95% CI] = 0.18 [-0.56, 0.92]). Umpire sensitivity (A) scores in Four-day, One-day, and T20 matches is illustrated in Fig. 2. Sensitivity scores of 1 indicate perfect performance, while scores of 0.5 indicate chance performance.

2.2. Response bias

Three one-sample Wilcoxon Signed Rank Tests showed a significant conservative response bias whereby umpires tended to respond not out in Four-Day ($Z = 3.46$, $p = .001$, $r = 0.82$), One-Day ($Z = 3.39$, $p = .001$, $r = 0.82$), and T20 Matches ($Z = 2.93$, $p = .003$, $r = 0.85$) (see Fig. 3). A Mixed Effects model with Match Type as a fixed effect, and umpire as a

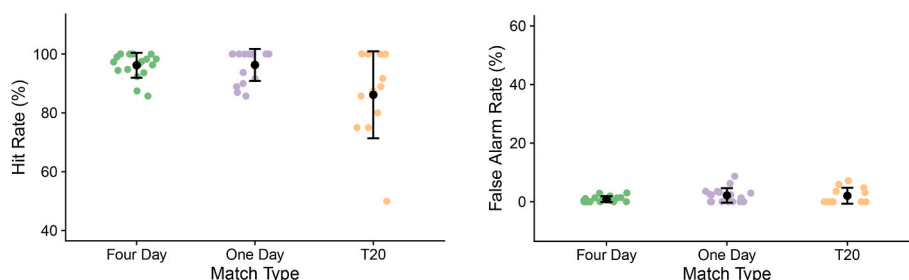


Fig. 1. Scatterplot of Hit and False Alarm Rates in LBW decisions across match types, with means and standard deviations.

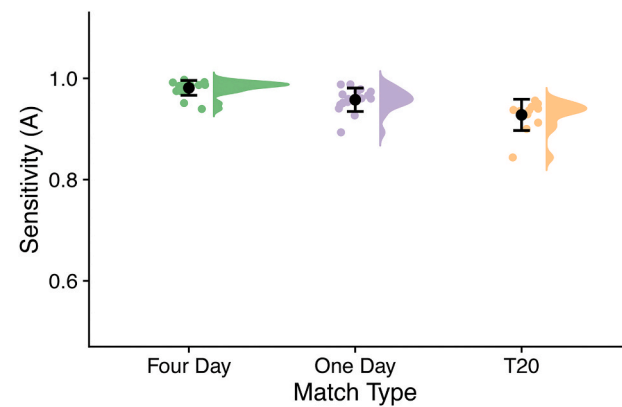


Fig. 2. Raincloud plot of umpire decision Sensitivity (A) across match types, with means and standard deviations. Sensitivity scores range from 0 to 1, with 0.5 meaning chance performance, and 1 meaning perfect performance.

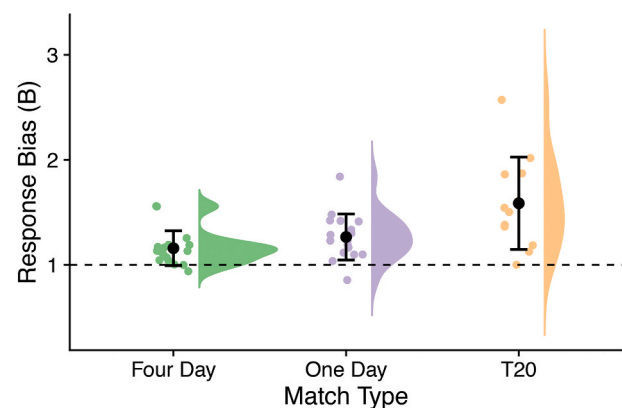


Fig. 3. Raincloud plot of umpire Response Bias (B) across match types, with means and standard deviations. Scores greater than 1 indicate a conservative bias to respond “not out”, while scores below 1 indicate liberal bias to respond “out”.

random effect revealed a significant main effect of match type on umpire response bias with a large effect size ($F(2, 12.39) = 6.56$, $p = .011$, $\eta_p^2 = 0.51$). Post-hoc comparisons showed that umpires were significantly more conservative in T20 compared to Four-Day Matches with a large effect size ($p = .018$, Cohen’s d [95% CI] = 0.87 [0.11, 1.63]). There was no significant difference in response bias between Four-Day and One-Day Matches ($p = .23$, Cohen’s d [95% CI] = 0.24 [-0.43, 0.91]), or between T20 and One-Day Matches ($p = .10$, Cohen’s d [95% CI] = 0.58 [-0.17, 1.33]). Umpire response bias (B) scores in Four-day, One-day, and T20 matches is illustrated in Fig. 2. Bias scores less than 1 indicate liberal response bias (tend to say out), while scores above 1 indicate conservative response bias (tend to say not out).

3. Discussion

The aim of this study was to better understand umpire LBW decision-making in cricket, and determine whether differences in decision-making were associated with match type. Previous explorations of LBW decision-making have relied on simplified lab-based tasks which may not reveal the true performance of experts (Van der Kamp, Rivas, Van Doorn, & Savelsbergh, 2008). This study assessed umpire performance using extensive historical match data from performance in the real matches to provide a more representative analysis of umpire performance.

We found that umpires were able to distinguish between out and not out appeals to a high standard. This level of performance is impressive when compared to officials' accuracy in baseball (86%) (MacMahon & Starkes, 2008), Australian Football (87%) (Elsworthy, Burke, & Dascombe, 2014), football (75%) (Catteeuw, Helsen, Gilis, Van Roie, & Wagemans, 2009), and rugby (53%) (Mascarenhas et al., 2005). Differences in this performance were associated with the specific match format in which the umpires were officiating. Umpires were less sensitive in the shorter formats of the game, particularly T20 cricket. Overall, umpires were conservative and tended to respond "not out". Umpires were significantly more conservative in T20 cricket compared to Four-day matches.

We see two potential reasons why cricket umpires' decision-making might vary across game formats. First, Di Corrado et al. (2011) propose that social pressure from spectators encourages officials to engage in behaviours which conform to the expectations of the group they are in. We postulate that increased scrutiny from significantly larger crowds and TV audiences in T20 cricket compared to Four-day matches, may result in an increased salience of the social norms associated with the sport. That is, umpires may be more likely to respond not out in order to conform to stakeholders' expectations that umpires give the batter the 'benefit of the doubt' and avoid 'false alarm' errors. As such, future studies should explore whether crowds and TV audiences influences normative behaviours in sports officiating.

Alternatively, the pattern of results may be explained by the recent findings of Russell et al. (2019), who proposed that officials' decisions are not only shaped by traditional notions of accuracy, but also task goals of fairness, entertainment, and safety. Because T20 cricket is heavily focussed on entertainment in the form of explosive batting performances, future research could explore whether this may be influencing how umpires make decisions. For example, if it is the case that batters are a large source of entertainment with one chance to contribute to a match, then it is possible that umpires will be more conservative for the sake of continuing entertainment, resulting in more 'miss' errors.

We also acknowledge the limitations of this study. First, match referees are typically former umpires and as such may be biased in favour of the umpires. Their assessments of umpire accuracy were subjective, and therefore may not be rooted in ground truth. However, we see no reason for any bias to differ across the three formats of the game. Second, the judgements made by the match referee were based on video footage of varying quality and from a viewpoint that differed to that of the on-field umpire. This footage is typically from a higher angle behind the bowler, rather than directly behind the stumps which may impact the accuracy of match referee judgments (Craig, 2013). However, research by Mann, Farrow, Shuttleworth, and Hopwood (2009) suggests that first-person viewpoints are not always better. Additionally, matches that were televised (i.e. T20 matches) had better quality footage for the match referees to assess. Further in T20 matches, match referees had access to ball tracking software to assist in assessing the decisions, while this technology was not available in other match types.

With these caveats in mind, future explorations of umpire performance could utilise ball tracking software in all three formats when comparing umpire decision-making performance. Further, it may be beneficial to include data from professional matches in other countries

and international games, to determine whether these findings transfer to other competitions.

This study has furthered our understanding of the LBW decision-making behaviour of cricket umpires, but it remains unclear what might be the cause(s) of these differences in behaviour. Future research could utilise a think aloud paradigm to assess umpire explicit decision-making processes between match types, and explore the underlying mechanisms of the behaviours presented in this study (Ericsson & Simon, 1984).

The findings of this study may influence future training practices of elite umpires. For example, future research could explore the underlying mechanisms of the effect we present here, in order to develop training practices which target the unique requirements of each match format. While not applicable to the present dataset, future research may also wish to explore how umpires make decisions in matches where the Decision Review System (DRS) is used, as the ability for players to challenge an umpire's decision may be an important contextual consideration. Further, similarly to some players specialising in some match format(s), future research could assess whether specialist umpires could be developed to handle the specific demands of officiating particular format(s).

4. Conclusion

The aim of this study was to better understand umpire LBW decision-making in elite-level cricket and determine whether differences in decision-making were associated with match type. We examined data from real matches and found that umpires are able to discriminate outs from not outs to a high standard and have a bias to judge a batter as being not out rather than out (i.e., they give the batter the "benefit of the doubt"). The study also showed that umpiring performance differs between match types, potentially due to the differing social pressures, or differing task goals associated with the different match formats. Future work should explore these explanations in a controlled environment, utilising ball-tracking software in order to assess umpire performance based on ground truth rather than subjective assessment.

CRediT authorship contribution statement

Joshua M. Adie: Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft, Visualization, Project administration. **Ian Renshaw:** Conceptualization, Methodology, Writing - review & editing, Supervision. **Remco Polman:** Conceptualization, Methodology, Formal analysis, Writing - review & editing, Supervision. **Matthew B. Thompson:** Conceptualization, Methodology, Formal analysis, Data curation, Writing - review & editing, Visualization, Supervision. **David L. Mann:** Conceptualization, Methodology, Writing - review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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